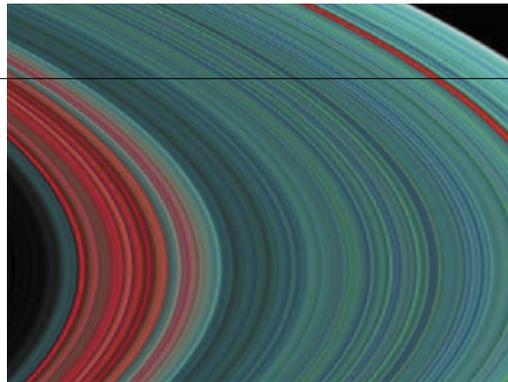


RESEARCH AND DEVELOPMENT AT NASA



“Audentes Fortunas Juvat” – Fortune Favors the Bold

From the beginning, exploration and discovery have driven human curiosity and enriched the cultures that embraced them. Exploration provides the foundation of our knowledge, technology, resources, and inspiration. As President Bush stated when he unveiled the [Vision for Space Exploration](#), “This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart.”

We are about to set forth on a journey that will mark the beginning of a sustained human presence in the solar system. Just take a moment to think about the possibilities this yields for our future. The exploratory voyages of the next few decades have the potential, in this lifetime, to answer age-old questions about how life begins, whether life exists elsewhere, and how the inevitable discoveries along the way will help better our lives here on Earth.

The Vision for Space Exploration seeks answers to fundamental questions about our existence, responds to recent discoveries, and puts in place revolutionary technologies and capabilities to inspire our Nation, the world, and the next generation...as only NASA can.

The extensive scope of technologies yielded from NASA research and exploration makes the notion that “NASA Explores, Humanity Benefits” even more relevant. From cancer detection and treatments used in hospitals throughout the world, to the treatment of Attention Deficit Hyperactivity Disorder, to the development of cordless power tools, technologies from NASA exploration have a major impact on our lives here on Earth. And to think, NASA has accomplished this with less than 1 percent of the Federal budget.

As we take our first steps towards sustaining a human presence in the solar system, we can look forward to far-off visions of the past becoming realities of the future. Whole industries that are currently unknown will unveil themselves, offering opportunities to our offspring that shall make their future, and their children’s future, brighter.

Over the next century, the Vision for Space Exploration will set in motion activities to improve our understanding of those age-old questions, and inspire new generations to pursue math and science. We will see those new industries and technologies evolve, and discoveries will benefit all mankind. The technologies developed for exploration will underpin and advance the U.S. economy and help to ensure national security. I look forward to sharing this future with all of you.



A handwritten signature in black ink, appearing to read 'Craig Steidle'.

RADM Craig E. Steidle (Ret.)
Associate Administrator,
Exploration Systems Mission Directorate

National Aeronautics and
Space Administration

The Vision for Space Exploration marks the next segment of NASA's continuing journey to find answers to compelling questions about the origins of the solar system, the existence of life beyond Earth, and the ability of humankind to live on other worlds.

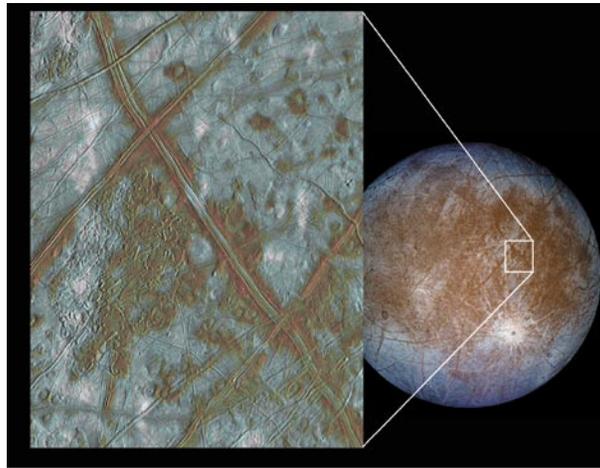
The success of the Vision relies upon the ongoing research and development activities conducted at each of NASA's 10 field centers. In an effort to promote synergy across NASA as it works to meet its long-term goals, the Agency restructured its Strategic Enterprises into four Mission Directorates that align with the Vision. Consisting of Exploration Systems, Space Operations, Science, and Aeronautics Research, these directorates provide NASA Headquarters and the field centers with a streamlined approach to continue exploration both in space and on Earth.

EXPLORATION SYSTEMS

The Exploration Systems Mission Directorate creates capabilities and supporting technologies that will permit sustainable and affordable human and robotic exploration. It includes the biological and physical research necessary to ensure the health and safety of crews during long-duration space flight. Led by Associate Administrator Rear Admiral Craig Steidle, USN (Ret.), the directorate actively supports the Vision for Space Exploration, ensuring that it is both achievable and affordable. The directorate will guide NASA's development of new systems for safe human missions to the Moon, Mars, and beyond.

JUPITER ICY MOONS ORBITER

The mission design requirement document for a proposed mission to Jupiter and its three icy moons was the first product formulated by NASA's new Exploration Systems Mission Directorate. The [Jupiter Icy Moons Orbiter](#) (JIMO) is a spacecraft with an ambitious proposed mission that would orbit the three planet-size moons of Jupiter (Callisto, Ganymede, and Europa), which may



The image shows a region of Europa's crust made up of blocks which are thought to have broken apart and "rafted" into new positions. These features provide geologic evidence that Europa may have had a subsurface ocean at some time in its past. Combined with the geologic data, the presence of a magnetic field leads scientists to believe an ocean is most likely present on Europa today.

harbor vast oceans beneath their icy surfaces. The mission would be powered by nuclear fission and launched sometime in the next decade.

Managed by NASA's Jet Propulsion Laboratory (JPL), the JIMO mission is part of NASA's Project Prometheus, a program studying a series of initiatives to develop power systems and technologies for space exploration. The JIMO endeavor would be the first NASA exploration mission utilizing nuclear electric propulsion, which would enable the spacecraft to orbit each of these icy worlds to perform extensive investigations of their makeup, history, and potential for sustaining life.

According to Steidle, "The Jupiter Icy Moons Orbiter requirements represent our new way of doing business, tracing exploration strategies to the technology maturation programs that will enable this exciting mission and the other missions that make up Project Constellation." Just as

the Apollo Program encompassed NASA's efforts to reach the Moon in the 1960s, Project Constellation embodies the Agency's new initiatives to fulfill the Vision for Space Exploration.

LIFEGUARD SYSTEM

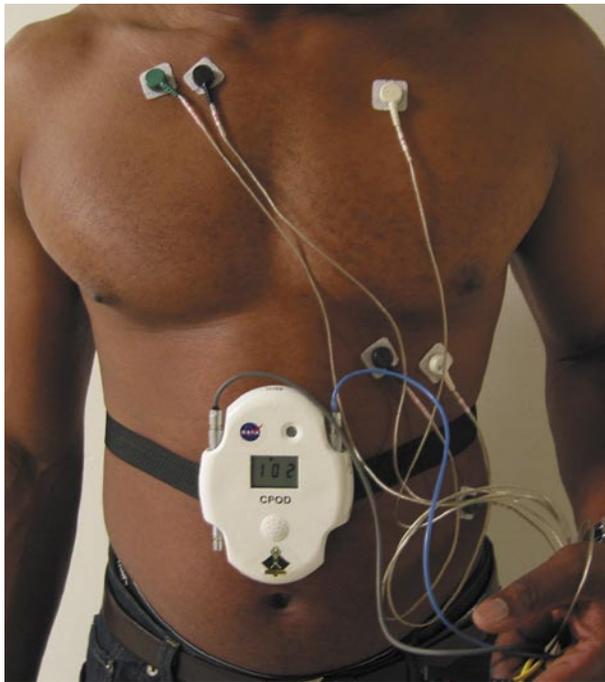
While NASA field centers such as JPL strive to develop more effective ways to safely power, propel, and maneuver spacecraft to explore worlds currently beyond our reach, other centers are preparing the technologies that will enable human beings to visit these worlds. An astrobionics team at NASA's Ames Research Center has focused on physiological monitors for the past decade, conducting research that supports the goals of the Exploration Systems Mission Directorate and the Vision for Space Exploration. The scientists recently developed the [LifeGuard system](#), a lightweight, portable device enabling physicians to monitor the health and safety of explorers in remote locations on Earth. The system may eventually be used in space to monitor astronauts during space travel.

The wireless LifeGuard system watched over the vital signs of several expedition members who sampled soils and water from the world's highest alpine lake, nearly 20,000 feet up the Licancabur volcano, on the border between Chile and Bolivia late in 2003. The LifeGuard units sent real-time vital signs from the members at the volcano to scientists at Ames by satellite. This proved the monitor's potential to work in an extreme environment. The test also demonstrated the enhanced ability for doctors to practice telemedicine over long distances on Earth or potentially in space.

The LifeGuard system allows real-time monitoring of vital parameters such as heart rate, blood pressure, electrocardiogram (EKG), breathing rate, and temperature. It can also measure human movements in three dimensions. The LifeGuard's button sensors stick to the skin to measure a person's EKG and breathing rate, and the device uses an arm cuff to measure blood pressure. The data logger

connects to a sensor clipped or wrapped on an index finger to measure oxygen in the blood and pulse rate.

“The data logger part of the system that collects data from body sensors is about the size of your palm and weighs about 166 grams (6 ounces),” explains Carsten Mundt, an engineer who is developing LifeGuard at Ames. According to Mundt, “The sensors we use are quite easy to apply and comfortable to wear.” In addition to potentially monitoring the health of astronauts on long-term spaceflights, the LifeGuard system may provide several applications on Earth. LifeGuard could be used by physicians on Earth to transmit a patient’s vital signs during transfer to the hospital, and it could also be worn to monitor patients at home



The LifeGuard system, which may eventually be used in space to monitor astronauts during space travel, recently monitored the vital signs of expedition members sampling soils and water from the world’s highest alpine lake.

to diagnose sleep disorders, heart disease, or unsteady gait in the elderly. Firefighters and hazardous material workers could also wear the device to monitor their health during dangerous activities.

MOBILE AGENT SOFTWARE

In the spring of 2004, NASA scientists began testing “mobile agent” software that eventually may help astronauts on Mars talk with mission control on Earth. The mobile agent software project, based at Ames Research Center, called upon researchers to play the role of astronauts during tests in Utah’s Southeast Desert. The “explorer astronauts” carried backpacks containing “smart” laptop computers that were loaded with the mobile agent software. The software, which scientists say may improve communications between human planetary explorers, robots, and mission support on Earth, comes in several types, including “personal agent” software—software to which people can speak—and “com” software, which links software and hardware devices.

The main objective of the effort was to test the mobile agent system while the explorer astronauts and a robotic assistant conducted real exploration in the desert. During the tests, each person’s laptop computer was equipped with personal agent software that could literally speak with them. NASA’s Glenn Research Center provided the satellite communications link from the Utah site to the NASA Research & Education Network located at Glenn. During the field work, the explorers used the mobile agent system to conduct real science, looking for geological evidence of past water in the desert as well as fossils from the Jurassic period.

During the tests, the explorers talked with the computer mobile agent software about science observations being made. They needed to relay the name of the location and identify which bag was being used to collect samples, while narrating the contents of the bag and the geologic context. The helper robot that took part in the tests, called the Extravehicular Activity (EVA) Robotic Assistant, followed along with the human explorers.

Developed at NASA’s Johnson Space Center, the EVA Robotic Assistant responds to voice commands. The explorer astronaut speaks through a microphone to the personal agent software, which relays commands to the robot’s personal agent software. This software activates computer programs that direct the robot to follow the explorer astronauts, take photographs, or carry samples.

During future planetary exploration, data will be relayed by personal agent software to others on the science team, both on the planet’s surface and back on Earth. Information will be stored in a database in a Mars or planetary human habitat. The personal agent software will send these data via e-mail to the Earth-bound science team. The software will also automatically transmit images taken by the astronauts to their planetary habitat and to Earth. The computer that astronauts will carry will include a global positioning system device, enabling the software agent to stamp the collected data with time and location.

The astronauts will also be able to tell the software agent what activity they are going to do next by choosing activities from a menu of potential planned subjects. The chosen activity sets up expectations for the personal agent software describing where the explorer should be and how long the activity should continue. If the astronaut deviates from the plan or the planned location, or stays too long, the personal agent software will verbally warn the astronaut. At the same time, the computer agent also will send e-mail to the support team on Earth and to another computer agent in the habitat, which will announce on the habitat’s loudspeaker that there is a possible problem.

During a mission, the astronauts will wear biosensors, possibly such as the ones designed for the LifeGuard system, which will detect and transmit human vital signs to his or her personal agent software. If vital signs are not normal, the agent software will send e-mail to Earth and broadcast a warning on the loudspeaker.



NASA scientists tested the mobile agent system while the explorer astronauts conducted real exploration in the desert.

ARTIFICIAL INTELLIGENCE SOFTWARE

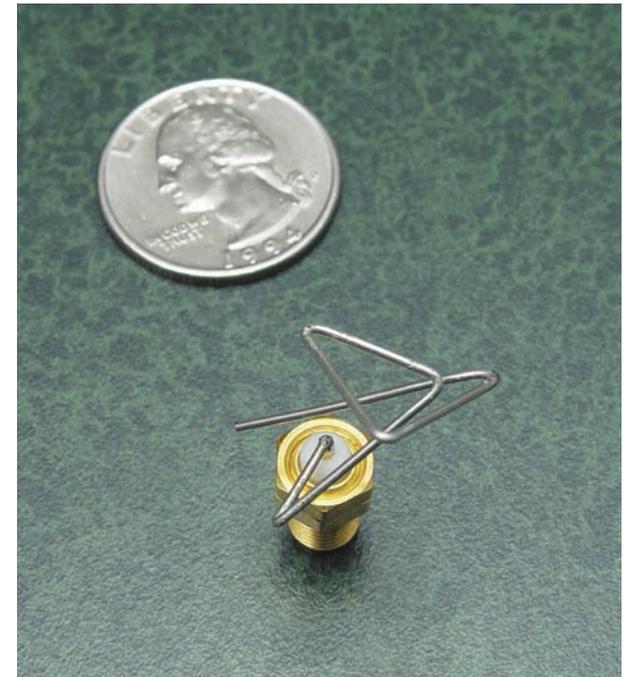
Other current research and development activities supporting the Exploration Systems Mission Directorate are exploring the ways that artificial intelligence (AI) can help engineers design advanced components for long-term spaceflight. Funded by the directorate, four computer scientists at Ames Research Center wrote the AI evolutionary program, which can create designs faster than a human

being. The software, which operates on 120 personal computers, can plan devices that are smaller, lighter, stronger, and consume less power—characteristics that meet spaceflight requirements.

The AI software's first task involved designing a satellite antenna scheduled to orbit Earth in 2005. The antenna, able to fit into a 1-inch space, can receive commands and send data to Earth from the Space Technology 5

satellites. The three satellites—each no bigger than an average television set—will help scientists study magnetic fields in Earth's magnetosphere.

According to project lead Jason Lohn, a scientist at Ames, "The AI software examined millions of potential antenna designs before settling on a final one." The software started with random antenna designs and refined them through the evolutionary process. It adapted existing designs quickly to meet changing mission requirements. Scientists also can use the evolutionary AI software to invent and create new structures, computer chips, and even machines. Lohn explains, "We are now using the software to design tiny microscopic machines, including gyroscopes, for spaceflight navigation."



This miniature antenna was developed using a NASA artificial intelligence software program that creates designs faster than a human being.

SPACE OPERATIONS

NASA's new Space Operations Mission Directorate is supported by Johnson Space Center, Kennedy Space Center, Stennis Space Center, and Marshall Space Flight Center. The directorate, led by Associate Administrator William F. Readdy, directs space flight operations, space launches, and space communications, as well as the operation of integrated systems in low-Earth orbit and beyond.

Johnson manages the development, testing, production, and delivery of all NASA human spacecraft, as well as all human spacecraft-related functions such as life support systems, space suits, and spacewalking equipment. Johnson also serves as the lead NASA center for the design and implementation of the International Space Station. Scheduled for completion around 2010, this working laboratory will serve as a stepping-stone to other planets by teaching the essentials of long-term living in space.

Kennedy's slogan, "Launching the NASA Vision," has never been more true or applicable as the Agency works diligently to return to flight safely and implement the Vision for Space Exploration. The Center will play a major role in these endeavors, since its dual mission includes space launch operations and spaceport and range technology development. The Spaceport Technology Center initiative carries out Kennedy's role within NASA to meet the goals of increased safety, reduced cost of space access, and rapid expansion of commercial markets by infusing spaceport technologies into all facets of current and future Space Transportation Systems.

VOLCANIC EMISSION MASS SPECTROMETER

A Kennedy research and development team recently used a new hazardous gas detection system to study volcanic emissions in Costa Rica. The new prototype system, named the "Aircraft-based Volcanic Emission Mass Spectrometer (AVEMS)," also will have a direct application to the Space Shuttle Program. The AVEMS is a step toward an advanced



Researchers record data as the hazardous gas detection system is used to analyze the toxic gases produced by active vents, called fumaroles, in the Turrialba volcano in Costa Rica.

system that will be able to detect toxic gas leaks and emissions in the Space Shuttle aft, or rear, engine compartment and the crew compartment, providing an added level of protection for the astronauts and the vehicle.

The Kennedy team used AVEMS to analyze gases vented from the [Turrialba volcano](#) in Costa Rica. The tests were conducted from the air and in the volcano's crater. Johnson provided the WB-57F aircraft and support for the nine research flights in the hazardous

gas study, while Ames provided infrared and visible photography as well as multispectral imaging on the mission.

The study was the first to sample and quantitatively analyze fresh volcanic gases in their natural state. Active vents in volcanoes, called fumaroles, produce toxic gases such as sulfur dioxide, hydrogen sulfide, and carbon dioxide, which, if too concentrated, can be fatal. "Hikers on the volcanoes sometimes get cold then are attracted to the warm vents. When a large vent is producing massive amounts of carbon dioxide, the carbon dioxide displaces oxygen,

which could be fatal to the hikers nearby,” explains NASA project lead, Dr. Tim Griffin.

The new system shows promise for commercial applications in a variety of environments and industries such as semiconductor, petrochemical, automotive, refrigeration, and cathode ray tube. The technology could be used for breath and blood analysis as well as for monitoring air quality in the workplace. “Mass spectrometer technology could be used to ensure public safety and equipment protection in so many areas,” says Griffin. “Previous mass spectrometer systems have been so expensive and bulky that their use was limited to laboratories.” The new system is small and mobile and is able to easily and accurately produce in-depth data.

WIRE INSULATION REPAIR

Another Kennedy research and development project is investigating innovative methods to repair damaged wire insulation that can lead to self-healing systems. The wire insulation used in the Space Shuttle is either Kapton® (a polyimide) or Teflon® (a polyfluorocarbon). Similar to other critical applications in the aircraft and nuclear industry, wire inspection and repair is important in keeping these systems safe. Existing insulation repair methods use similar repair materials, and either wrap the damaged area with mystic tape and secure the ends with tie-wraps or melt a fluorocarbon polymer over the damaged area with a heat gun. These methods result in poor adhesion to the damaged insulation and can cause breaks at each end of the repair.

NASA’s new repair methods for Kapton synthesize a polyimide on the surface of the damaged insulation, producing an excellent seal with very high adhesive forces. In addition to using this technology on the Space Shuttle, NASA has been awarded funding from the Federal Aviation Administration’s aging aircraft group and is seeking partners to co-develop and commercialize self-healing insulation repair.



A Space Shuttle Main Engine undergoes a test firing on the A-1 Test Stand at Stennis Space Center.

SPACE SHUTTLE MAIN ENGINE ADVANCES

Stennis Space Center is NASA’s primary center for testing and proving flight-worthy rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Having conducted engine testing for 4 decades, Stennis is NASA’s program manager for rocket propulsion testing with total responsibility for conducting and managing all NASA propulsion test programs.

The [Space Shuttle’s Main Engines](#) (SSMEs) reached a significant milestone on January 21, 2004, by surpassing 1 million seconds of successful test and launch firings during a flight acceptance test. The engine test, conducted at Stennis, ran for 8.5 minutes, the length of time it takes the Space Shuttle to achieve orbit. “This

1 millionth-second test is a testimony to the NASA and contractor team that developed, tested, and continues to improve the SSME to safely take humans to low-Earth orbit,” said NASA’s Miguel Rodriguez, director of the Propulsion Test Directorate at Stennis.

Developed in the 1970s, the SSMEs are the world’s most sophisticated reusable rocket engines. Each powerful engine is 14 feet long, weighs about 7,000 pounds, is 7.5 feet in diameter at the end of its nozzle, and generates nearly 400,000 pounds of thrust. The rigorous testing used to verify that an engine is ready to fly is critical to any flight program. According to Michael Rudolphi, Space Shuttle propulsion manager, “The Main Engine that flies today has gone through major upgrades and is safer, stronger, and more reliable than the one that flew on STS-1 in 1981. Reaching this milestone is a historic moment for the Space Shuttle Program.”

In another effort to return the Space Shuttle safely to flight, engineers with Stennis’ Propulsion Test Directorate recently modified two test stands for Space Shuttle flow liner testing. Flow liners, located in the Space Shuttle’s main propulsion system fuel feed lines, protect flexible joints from the liquid hydrogen fuel as it feeds toward the SSME turbopumps. Small cracks have been found in the flow liners inside the hydrogen fuel lines aboard the NASA orbiters Atlantis, Discovery, and Endeavour. The cracks were first found in June 2002, resulting in concern that a piece of flow liner material may work free and enter the SSME turbopumps, causing potential for a premature engine shutdown in flight. After extensive testing and analysis, the existing cracks on the orbiters’ flow liners were repaired by welding.

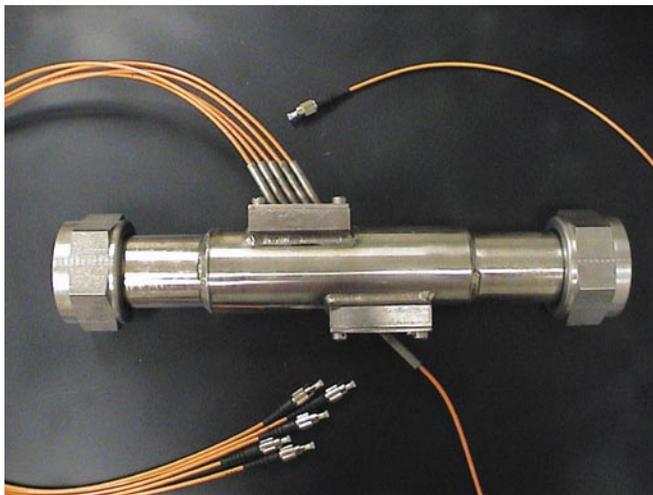
Stennis has reactivated the A-1 Test Stand to accommodate additional SSME upgrade testing and the E-1 Cell 2 Test Position articles are being activated to accommodate future flow liner testing that will be used to gather data while simulating the actual flight environment. The fuel duct on the A-2 Test Stand is also being modified to support fuel flow characterization efforts. The A-2 stand

currently supports SSME testing and certification for flight. The A-1 stand was used for testing the SSME until last summer, when refurbishment of the A-2 stand was completed and all SSME test activities were transferred there.

“We are proud of the effort that was put forth by our A-1 Activation Team,” asserts Ronnie Rigney, deputy project manager of the SSME Project Office at Stennis. “Successful completion of the A-1 Activation test demonstrated that we are ready to support the Space Shuttle Main Engine Test Program in its Return to Flight work.”

FIBER-OPTIC MASS FLOW SENSOR

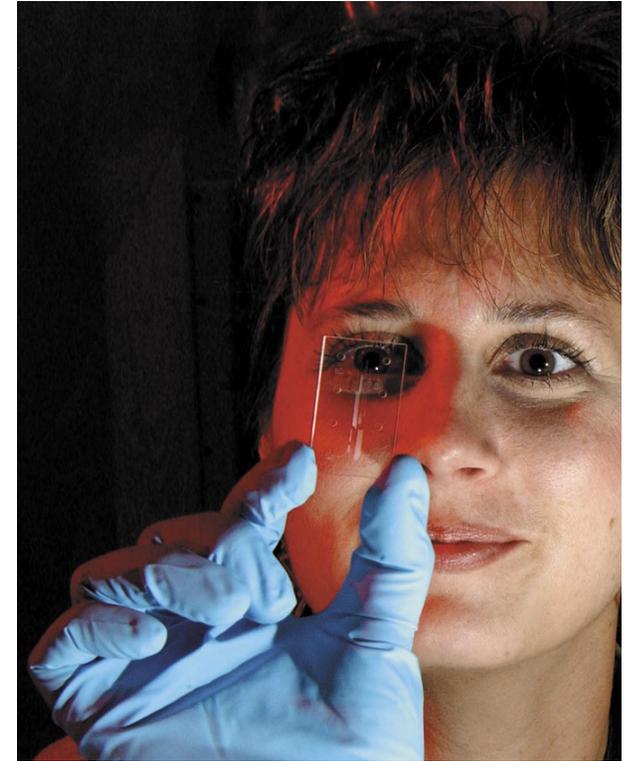
Marshall Space Flight Center recently developed a technology that both supports the Vision for Space Exploration and offers opportunities for commercial partnerships with private industry. Companies can license Marshall’s new fiber-optic mass flow sensor system, which was originally developed to accurately determine the flow rates and tank levels of multi-phase cryogenic fuels used on various NASA vehicles, including the Space Shuttle, and in ground-based propulsion testing.



Capable of measuring multi-phase flows in a pipe, the technology is minimally invasive, cost effective, retrofitable, and compact. Marshall’s new technology combines high accuracy, intrinsically safe operation, and low-cost flow sensing for virtually any optically transparent medium, providing a superior product for measuring multi-phase flows. Possible applications include oil and gas industry multi-phase flows; industrial, automotive, and aerospace multi-phase flows; powder spray coatings; food processing; and chemical processing, handling, and storage.

LAB-ON-A-CHIP TECHNOLOGY

Another current Marshall research and development effort involves the study of “lab-on-a-chip” technology. The technology allows chemical and biological processes—previously conducted on large pieces of laboratory equipment—to be performed on a small glass plate with fluid channels, known to scientists as microfluidic capillaries. Dr. Helen Cole, project manager for the Lab-on-a-Chip Applications Development program, explains, “We are studying how lab-on-a-chip technology can be used for new tools to detect bacteria and life forms on



Dr. Lisa Monaco, the project scientist for the Lab-on-a-Chip Applications Development program, examines a lab on a chip. The small dots are actually ports where fluids and chemicals can be mixed or samples can be collected for testing.

Earth and other planets, and for protecting astronauts by monitoring crew health and detecting microbes and contaminants in spacecraft.”

The Marshall team is collaborating with scientists at other NASA centers and universities to design chips for many applications, such as studying how fluidic systems work in spacecraft and identifying microbes in self-contained life support systems. Since the chips are small, a large number of them can be carried on a Mars rover to search for life or carried on long-duration human exploration missions for monitoring microbes inside lunar or Martian habitats.

SCIENCE

NASA's Science Mission Directorate, headed by Alphonso V. Diaz, carries out the scientific exploration of the Earth, Moon, Mars, and beyond; charts the best route of discovery; and reaps the benefits of Earth and space exploration for society. By combining Earth and space studies, NASA is best able to establish an understanding of the Earth and the surrounding solar system, to assure the discoveries made here will enhance our work there, and vice versa.

MARS EXPLORATION ROVER MISSION

Headlining NASA's research efforts in the areas of science and discovery, the [Mars Exploration Rover mission](#) has been turning up valuable data regarding the Red Planet's past and present environment, thanks to a loyal mission team managed by JPL and two determined robotic explorers, Spirit and Opportunity. The big science question for the mission team is how past water activity on Mars has influenced its environment over time. While liquid water cannot exist for long on the surface of Mars today, the record of past water activity on Mars can be found in the rocks, minerals, and geologic landforms, particularly in those that can only form in the presence of water. That is why the rovers are specially equipped with tools to study a diverse collection of rocks and soils that may hold clues to past water activity on Mars.

Spirit and Opportunity are offering unique contributions in pursuit of the overall Mars science strategy to “follow the water.” Understanding the history of water on Mars is important to meeting the four science goals of NASA's long-term Mars Exploration program: Determine whether life ever arose on Mars, characterize the climate of Mars, characterize the geology of Mars, and prepare for human exploration.

Spirit traveled 487 million kilometers (302.6 million miles) and nearly 7 full months to reach Mars after its launch from Cape Canaveral Air Force Station on June 10, 2003. On January 3, 2004, Spirit landed on Mars



Clues from a wind-scalloped volcanic rock on Mars investigated by NASA's Spirit rover suggest repeated possible exposures to water inside Gusev Crater.

and successfully sent a radio signal to notify the mission team of its historic arrival. NASA chose Gusev Crater as Spirit's landing site, based on evidence from Mars orbiters that this crater may have held a lake long ago. A long, deep valley, apparently carved by ancient flows of water, leads into Gusev. The crater itself is a basin the size of Connecticut, created by an asteroid or comet impact early in the planet's history.

While the rover worked to free itself from its lander platform over the next 12 days, it did not waste any time in taking panoramic pictures of its new “neighborhood” to send back to Earth. The initial images—the highest-resolution pictures ever sent from Mars and more than 3 times as detailed as images from Mars Pathfinder in 1997—excited the mission's scientists about the prospects of exploring the region.

On January 15, Spirit rolled all six of its wheels onto Martian soil to begin what was originally scheduled as a 90-day adventure to explore Mars. Research was underway the next day, as Spirit reached out with its versatile robotic arm and examined a patch of fine-grained soil with a microscope at the end of the arm. One unexpected finding was the detection of a mineral called olivine, which does not survive weathering well. According to the mission scientists, the lack of weathering suggested by the presence of olivine might be evidence that the soil particles are finely ground volcanic material. Another possible explanation is that the soil layer where the measurements were taken is extremely thin, and the olivine is actually in a rock under the soil. The most prevalent elements detected in the soil patch were silicon and iron. Significant levels of chlorine and sulfur were also found, characteristic of soils at previous Martian landing sites but unlike soil composition on Earth. The scientists believe that the soil may not have even originated anywhere near Spirit's landing site, because Mars has dust storms that redistribute fine particles around the planet. The next target for use of the rover's full set of instruments was a rock the mission team named "Adirondack," which was more likely to have originated nearby.

Prior to the chance to study Adirondack, Spirit temporarily stopped communicating on January 22. The problem was later diagnosed as a memory-management issue. Engineers regained partial control of the spacecraft within days and reformatted the rover's flash memory to prevent recurrence of the problem. Meanwhile, NASA's second Mars Exploration Rover, Opportunity, successfully sent signals to Earth during its January 25 landing in a region of Mars called Meridiani Planum, halfway around the planet from the Gusev Crater site. A healthy Spirit got back to work 4 days after the arrival of its twin, and resumed its pursuit to examine Adirondack. Spirit grinded the rock with an abrasion tool to reveal its interior. Mission scientists were able to confirm from the sublayer's properties that Adirondack was volcanic basalt, a predominant material found on the planet's surface. In spite of this, further examination of Martian rocks would turn up more promising results.

In early March, Opportunity found strong evidence that the region of Meridiani Planum was once wet. A rock outcrop dubbed "Guadalupe" yielded clues that made the case for a watery history, such as the presence of sulfates and crystal-filled niches. "Liquid water once flowed through these rocks. It changed their texture and it changed their chemistry," says Dr. Steve Squyres of Cornell University, Ithaca, New York, and principal investigator for the science instruments on the two rovers. "We've been able to read the tell-tale clues the water left behind, giving us confidence in that conclusion." On Earth, rocks with as much salt as this outcrop of Mars rocks either have formed in water or, after formation, have been highly altered by long exposures to water.

Back at the Gusev Crater, Spirit found hints of a water history in a rock—albeit a very different type of rock than those in which Opportunity found clues to a wet past. A dark volcanic rock dubbed "Humphrey," about 2 feet tall, shows bright material in interior crevices and cracks that looks like minerals crystallized out of water, according to the team scientists. The amount of water suggested by the possible crystals in Humphrey is far less than what is indicated by the minerals and structures that Opportunity revealed in the Guadalupe rock outcrop, indicating that Mars is a diverse planet.

Further clues uncovered by Opportunity caused the mission team to deduce that some rocks on Mars probably formed as deposits at the bottom of a body of gently flowing saltwater. "We think Opportunity is parked on what was once the shoreline of a salty sea on Mars," Squyres notes. The evidence continued to mount up in early April when Spirit grinded down a wind-scalloped volcanic round and found a fracture in which water may have flowed through at one time.

Given the success of the rovers, NASA decided to extend the mission, handing Spirit and Opportunity up to 5 months of overtime assignments.

AURA EARTH-OBSERVING MISSION

In searching for conditions that might support life on other planets, one of the first things to look for is water—as in the case of the Mars rovers—but the thin sliver of gases and air that make an atmosphere around a planet is just as necessary for life to exist. On July 15, NASA launched [Aura](#), a next-generation, Earth-observing satellite managed by Goddard Space Flight Center that will supply the best information yet about the health of Earth's atmosphere, according to the Space Agency. Aura will provide an essential component for understanding changes in our climate, our air quality, and the ozone layer that protects life from harmful solar radiation. In doing so, it will help answer some fundamental questions regarding climate change.

One question that researchers have asked is: "Is the stratospheric ozone layer recovering?" International agreements have banned ozone-destroying chemicals like chlorofluorocarbons (CFCs), but scientists are unclear about the effectiveness of these treaties. Aura will accurately detect global levels of CFCs, and their byproducts, chlorine and bromine, which destroy the ozone layer.

Another question to which researchers need more information is: "What are the processes controlling air quality?" Aura will help greatly to unravel some of these mysteries by tracking the sources and processes controlling global and regional air quality. When ozone exists in the lower atmosphere, the troposphere, it acts as an air pollutant. Gasoline and diesel engines give off gases in the summer that create ozone and smog. Aura will help scientists follow the sources of ozone and its precursors.

Additionally, Aura will offer insights into the question: "How is the Earth's climate changing?" As the composition of Earth's atmosphere changes, so does its ability to absorb, reflect, and retain solar energy. Greenhouse gases, including water vapor, trap heat in the atmosphere. Airborne aerosols from human and natural sources absorb or reflect solar energy based on color, shape, size, and substance.

The impact of water vapor and aerosols on Earth's climate remains largely unquantified, but now Aura will have the unique ability to monitor these agents.

Aura's space-based view of the atmosphere and its chemistry will complete the first series of NASA's Earth Observing System satellites. The other satellites are Terra, which monitors land, and Aqua, which observes Earth's water cycle.

CASSINI-HUYGENS MISSION

An extensive tour of Saturn, its majestic rings, and its 31 known moons is currently underway, following a nearly 7-year journey to the planet.

Launched October 15, 1997, from Cape Canaveral Air Force Station, Cassini is the most instrumented and scientifically capable planetary spacecraft ever flown. It aims to fulfill the [Cassini-Huygens mission](#), a cooperative project of NASA, the European Space Agency, and the Italian Space Agency. The 4-year mission, managed by JPL, will draw upon the spacecraft's 18 highly sophisticated science instruments to study the Saturnian system in detail.

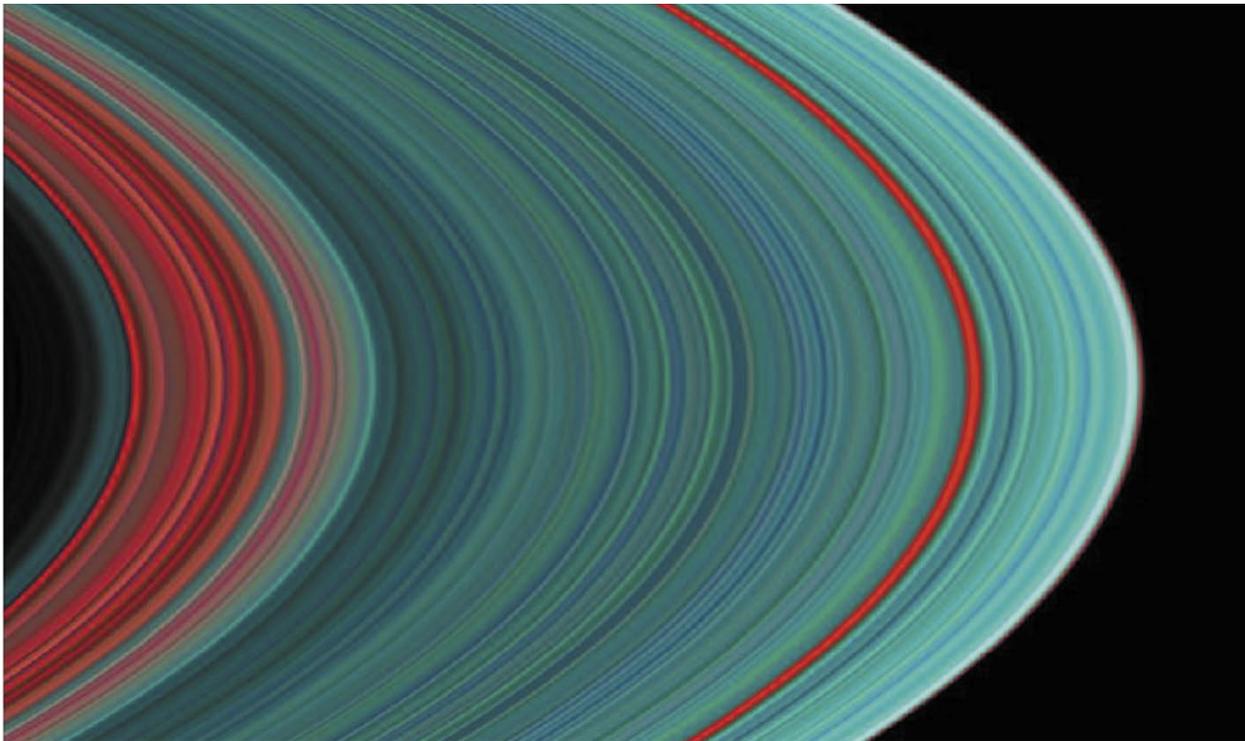
Cassini's first stop on its historical tour of Saturn was a June 11 fly-by visit of Phoebe, Saturn's largest outer moon. Data collected from the fly-by indicate that Phoebe may be a frozen artifact of a bygone era, some 4 billion years ago, like a woolly mammoth trapped in Arctic ice. Mission

scientists concluded that Phoebe is likely a primordial mixture of ice, rock, and carbon-containing compounds, and further believe bodies similar to this moon were plentiful in the outer reaches of the solar system long ago.

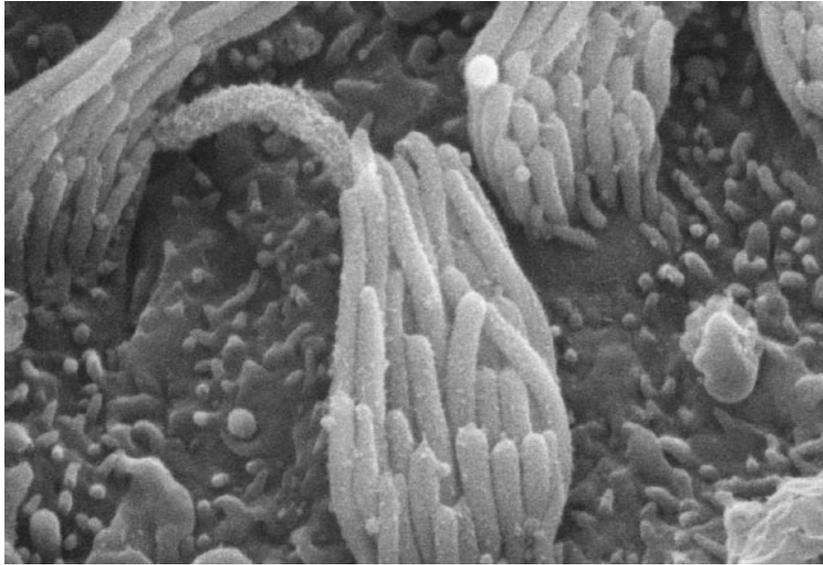
The international Cassini-Huygens mission successfully entered orbit around Saturn on June 30 of this year, after completing a critical 96-minute main engine burn that was calculated to slow the spacecraft by 626 meters per second, or 1,400 miles per hour. According to Robert T. Mitchell, program manager for the mission, orbit insertion is "sort of like applying your brakes while driving your car downhill. Although you've got your foot on the brakes, you still pick up speed as a steep gravity pulls you in." During the orbit insertion, Cassini flew closer to Saturn than it will at any other time during the planned mission.

Just 2 days after Cassini entered Saturn's orbit, preliminary science results from breathtaking images and scientific measurements showed a complex and fascinating planetary system. One early result concerns Saturn's Cassini Division, the large gap between the "A" and "B" rings. While Saturn's rings are almost exclusively composed of water ice, new findings show the Cassini Division contains relatively more "dirt" than ice. Further, the particles between the rings seem remarkably similar to dark material that scientists saw on Phoebe. These dark particles refuel the theory that the rings might be the remnants of a moon. Also, Cassini's ultraviolet imaging instrument detected the sudden and surprising increase in the amount of atomic oxygen at the edge of the rings. The finding leads scientists to hypothesize that something may have collided with the main rings, producing the excess oxygen.

Still to come, the Cassini spacecraft and its piggybacking Huygens probe (built by the European Space Agency) will target Saturn's largest moon, Titan. "In the 350 years since the discovery of Titan we have come to see it as a world with surprising similarities to our own, yet located almost 1.5 billion kilometers (900 million miles) from the Sun," said Dr. Jonathan Lunine, Huygens interdisciplinary scientist and professor of planetary science and physics



This image, taken with Cassini's Ultraviolet Imaging Spectrograph instrument, indicates that there is more ice toward the outer part of Saturn's rings than the inner part.



High-resolution image of the hair bundle (stereocilia and kinocilium) of a horizontal semicircular canal hair cell in a young chicken, taken with a scanning electron microscope (16,250 times magnitude). The electron micrograph was obtained during a remote collaborative scientific activity between NASA Ames' Visualization, Imaging, and Simulation Technology Center and the National Institute of Deafness and Other Communication Disorders in Bethesda, Maryland.

at the University of Arizona, Tucson. "With a thick, nitrogen-rich atmosphere and possible hydrocarbon seas, Titan may harbor organic compounds important in the chain of chemistry that led to life on Earth."

On December 24—6 months after reaching Saturn—Cassini will release the wok-shaped Huygens probe towards Titan. The event will be by far the most distant descent of a robotic probe on another object in the solar system. On January 14, 2005, Huygens will enter Titan's atmosphere, deploy its parachute, and begin its scientific observations of Titan.

REMOTE SCANNING ELECTRON MICROSCOPY

In another far-reaching extension of NASA's scientific know-how, researchers for the first time can study laboratory specimens from thousands of miles away by remotely operating NASA's new "super magnifying glass."

The Remote Scanning Electron Microscopy (RSEM) technology was developed at Ames Research Center, and has

been successfully tested to allow scientists to help NASA solve problems encountered by astronauts during long-duration spaceflights.

"This technology will enable multiple researchers at locations across the country to observe and control the scanning electron microscope, thus allowing for remote, real-time simultaneous analysis of tissue by several investigators," notes Dr. Richard Boyle, director of the [Biological Visualization, Imaging, and Simulation Technology Center](#) at Ames.

In contrast to conventional microscopes that use light waves, the RSEM uses electrons to magnify details of tissue from 10 to 100,000 times. This "super-dissecting microscope" illuminates the sample with a great depth of field and produces three-dimensional, high-resolution images. All scientists need to use the RSEM is a suitable Web browser and network access to connect to the instrument. A remote-control system on the microscope enables real-time interface with the tissue researchers are studying.

The technology is being utilized in a collaborative project with the National Institute of Deafness and Other Communication Disorders in an attempt to unravel key developmental processes of structures of the inner ear involved in hearing. "The inner ear cells change when you are in space and this impacts astronauts' health," claims NASA astronaut and physician Dr. Yvonne Cagle. "If we understand how these hair cells reposition themselves, we can better understand what happens over a long period of time in space."

AERONAUTICS RESEARCH

The Aeronautics Research Mission Directorate, led by Associate Administrator Dr. J. Victor Lebacqz, is committed to developing tools and technologies that can help to transform how the air transportation system operates, how new aircraft are designed and manufactured, and how our Nation's air transportation system can reach unparalleled levels of safety and security. Such tools and technologies will drive the next wave of innovation, enabling missions to be performed in completely new ways and creating new missions that were never before possible. The three NASA field centers that make up the directorate are: Dryden Flight Research Center, Glenn Research Center, and Langley Research Center.

As NASA's primary installation for flight research, Dryden Flight Research Center sits on the northwest edge of Rogers Dry Lake, at Edwards Air Force Base in Southern California's high desert. Since its creation in 1946, Dryden has advanced the design and capabilities of many civilian and military aircraft. To demonstrate improved reliability, capability, and enhanced safety, new technologies and new vehicles for both aviation and space flight require validation through flight testing. Dryden's workforce expertise in aeronautics and in the development of flight research tools and techniques, coupled with the suite of specialized laboratories and facilities needed for flight validation, are key to the development and maturation of new vehicles. Dryden operates a variety of

specialized aircraft that are used to verify a technology's performance, validate its safety and reliability, and discover any previously unknown problems.

Glenn Research Center, located in Cleveland, Ohio, and founded in 1941, provides research leadership in power and propulsion technologies for aircraft and spacecraft applications, aerospace communications, microgravity fluid physics and combustion, and bioscience and bioengineering. Glenn researchers are working to develop, verify, and transfer air-breathing propulsion technology for subsonic, supersonic, hypersonic, general aviation, and high-performance aircraft and rotorcraft, along with conducting fundamental research in propulsion-related specialties and new technologies, such as high-temperature nanomaterials, nanodevices, and computational intelligence. In the area of aerospace communications, Glenn develops communication and network architectures, systems modeling, and

enabling technologies for global communications network connectivity and integrated communications, navigation, surveillance, and weather information.

Langley Research Center, located in Hampton, Virginia, and established in 1917, is renowned for scientific and technological expertise in aerospace research, systems integration, and atmospheric science. Langley leads NASA initiatives in aviation safety and security, quiet-aircraft technology, small-aircraft transportation systems, and aerospace vehicles systems technology. The Center's unique infrastructure of wind tunnels, laboratories, and equipment arrays have enabled researchers to develop, validate, and deliver to the commercial sector technologies to improve the effectiveness, capability, efficiency, and safety of the Nation's air transportation system. Langley supports space programs with atmospheric research and technology testing and development. The Center serves a principal

role in understanding our planet through uniquely developed atmospheric missions, measurement instruments, and climate prediction data.

X-43A HYPERSONIC RESEARCH AIRCRAFT

In a combined research effort involving Dryden, Langley, and several industry partners, NASA recently demonstrated the value of its [X-43A hypersonic research aircraft](#), as it became the first air-breathing, unpowered, scramjet-powered plane to fly freely by itself. The March 27 flight, originating from Dryden, began with the Agency's B-52B launch aircraft carrying the X-43A out to the test range over the Pacific Ocean off the California coast. The X-43A was boosted up to its test altitude of about 95,000 feet, where it separated from its modified Pegasus booster and flew freely under its own power.

Two very significant aviation milestones occurred during this test flight: First, controlled accelerating flight at Mach 7 under scramjet power, and second, the successful stage separation at high dynamic pressure of two non-axisymmetric vehicles. To top it all off, the flight resulted in the setting of a new aeronautical speed record. The X-43A reached a speed of over Mach 7, or about 5,000 miles per hour faster than any known aircraft powered by an air-breathing engine has ever flown.

Hyper-X, NASA's multi-year experimental hypersonic ground and flight test program for the X-43A, is demonstrating air-breathing engine technologies that promise to increase payload capacity—or reduce vehicle size for the same payload—for future hypersonic aircraft and/or reusable space launch vehicles. As envisioned, payload capacity will be increased by discarding the heavy oxygen and associated tanks that rockets must carry by using a propulsion system that uses the oxygen in the atmosphere as the vehicle flies at many times the speed of sound. Hydrogen fuels the X-43A's scramjet engine, which scoops oxygen from the atmosphere for combustion.



The X-43A hypersonic research aircraft and its modified Pegasus booster rocket accelerate after launch from NASA's B-52B launch aircraft over the Pacific Ocean.



In-flight icing research activities will soon be aided by a new addition to Glenn Research Center. A former U.S. Navy S-3 Viking aircraft was recently transferred to NASA and will undergo modifications to provide a state-of-the-art flying laboratory in 2006.

S-3 VIKING ICING RESEARCH AIRCRAFT

Meanwhile, at Glenn, researchers under NASA's [Aviation Safety and Security program](#) are preparing to retire a 22-year-old icing research "workhorse" in order to accommodate a successor that will provide increased power, speed, and range. The S-3 Viking, a former U.S. Navy aircraft, will replace Glenn's current icing research aircraft, a DeHavilland Twin Otter, with initial research flights scheduled to be performed in 2006. The S-3 Viking arrived at Glenn in March and is being modified by the Center's technicians to incorporate diagnostic tools and allow for in-flight icing weather forecasts.

The DeHavilland Twin Otter icing research aircraft has helped Glenn in studying icing cloud characterization, natural icing physics studies, full-scale iced aircraft aerodynamics, and ice protection development. It has also helped solve the problems of tail plane stall and super-cooled large droplet dangers. However, to support NASA's new aviation safety objectives, strategic icing research plans have identified that icing flight research will require increased capability in range, speed, payload, and onboard power beyond the Twin Otter's capabilities.

The S-3 Viking's range and speed will enable research flights from Cleveland to Wyoming and back in a single day. These increased capabilities are essential in the areas of improved

aviation weather forecast development, icing simulation tool development, icing cloud characterization, identification and simulation of aerodynamic effects of icing, and continued development of education and training materials for modern regional and general aviation/business aircraft operators.

The NASA Aviation Safety and Security program is a partnership with the Federal Aviation Administration, aircraft manufacturers, airlines, and the U.S. Department of Homeland Security that is working to reduce the fatal aircraft accident rate and protect air travelers and the public from security threats.

As NASA begins its new quest to achieve the Vision for Space Exploration, the research and development efforts across the Agency will continue to bring cutting-edge technologies to the American public. These innovations will help build the future, while protecting and improving the world today.

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